INEEL/CON-02-00693
PREPRINT

Idaho National Engineering and Environmental Laboratory

Integrating Modeling and Monitoring for the Radioactive Waste Management Complex

R. R. Seitz
J. M. McCarthy
K. K. Keck

August 4, 2002 – August 8, 2002

Spectrum 2002

Integrating Modeling and Monitoring for the Radioactive Waste Management Complex

Roger R. Seitz, James M. McCarthy, and Karen N. Keck
Idaho National Engineering and Environmental Laboratory
P.O. Box 1625, MS 4142
Idaho Falls, ID 83415
E-mail: seitrr@inel.gov

Abstract— *United States Department of Energy Order 435.1, Radioactive Waste Management, includes requirements for assessing the long-term performance of radioactive waste disposal facilities and also for environmental monitoring of the performance of those facilities throughout the time of institutional control. It is also specified that performance assessment and composite analysis modeling should be integrated with environmental monitoring in order to provide a means to assess the adequacy of the assumptions that were made for the modeling. This paper describes the development of action levels, which are expected concentrations at different locations in the subsurface based on modeling conducted for the performance assessment and composite analysis for the low-level waste disposal facility at the Radioactive Waste Management Complex at the Idaho National Engineering and Environmental Laboratory. First year comparisons of measured concentrations with the action levels have shown that migration appears to be occurring at a much lower rate than predicted by the models. This supports the conclusion that the modeling is conservative and conclusions based on the modeling are likewise conservative.*

I. INTRODUCTION

United States Department of Energy (DOE) Order 435.1, Radioactive Waste Management[1], includes requirements for assessing the long-term performance of radioactive waste disposal facilities and also for monitoring of the performance of those facilities throughout the time of institutional control (100 years after closure). Long-term compliance with performance objectives specified in DOE Order 435.1 is demonstrated using performance assessments (PAs) to address radiological releases from wastes disposed in a low-level radioactive waste (LLW) disposal facility and composite analyses (CAs) to address all potential radiological sources surrounding a disposal facility in addition to the disposal facility itself.

DOE Order 435.1 identifies the need to link environmental monitoring with modeling predictions from the PA and CA for a given facility. To meet this requirement, a formal PA/CA monitoring program[2] and accompanying action levels were developed for the Radioactive Waste Management Complex (RWMC) Subsurface Disposal Area (SDA) at the Idaho National Engineering and Environmental Laboratory (INEEL) (see Figure 1). Monitoring locations and sampling frequencies are chosen based on the projected migration pathways and the potential to exceed the releases projected in the performance assessment[3] and composite analysis[4] that were conducted for the active LLW disposal facility located in the SDA at the RWMC.

Action levels are essentially thresholds, which are intended to indicate concentrations at which migration of radionuclides may be in excess of that predicted for the PA and CA. Thus, if the action levels are exceeded, prescribed activities must occur. Examples of responses to exceeding an action level include:

- immediate notification of the Waste Generator Services Department at the INEEL,
- immediate evaluation and documentation of the data collected,
- increased sampling frequency at the location where the action level was exceeded,
- assessment of the need for corrective actions,
- potential reduction in disposal of certain waste streams, and
- the potential development of mitigating actions to be undertaken to restore facility performance.

Action levels are determined for the radionuclides that significantly contribute to the dose predicted in the PA and CA. In the vadose zone and aquifer, the emphasis of monitoring is on mobile radionuclides in the liquid phase (i.e., C-14, I-129, Cl-36). If migration of radioactive materials is greater than expected, mobile radionuclides are most likely to be early indicators. Carbon-14 was the primary radionuclide of concern in the assessments, thus C-14 will be used as the example in this paper. The emphasis of this paper is also on the vadose zone, because monitoring in the vadose zone will provide the first indication of a potential problem for the groundwater pathway.

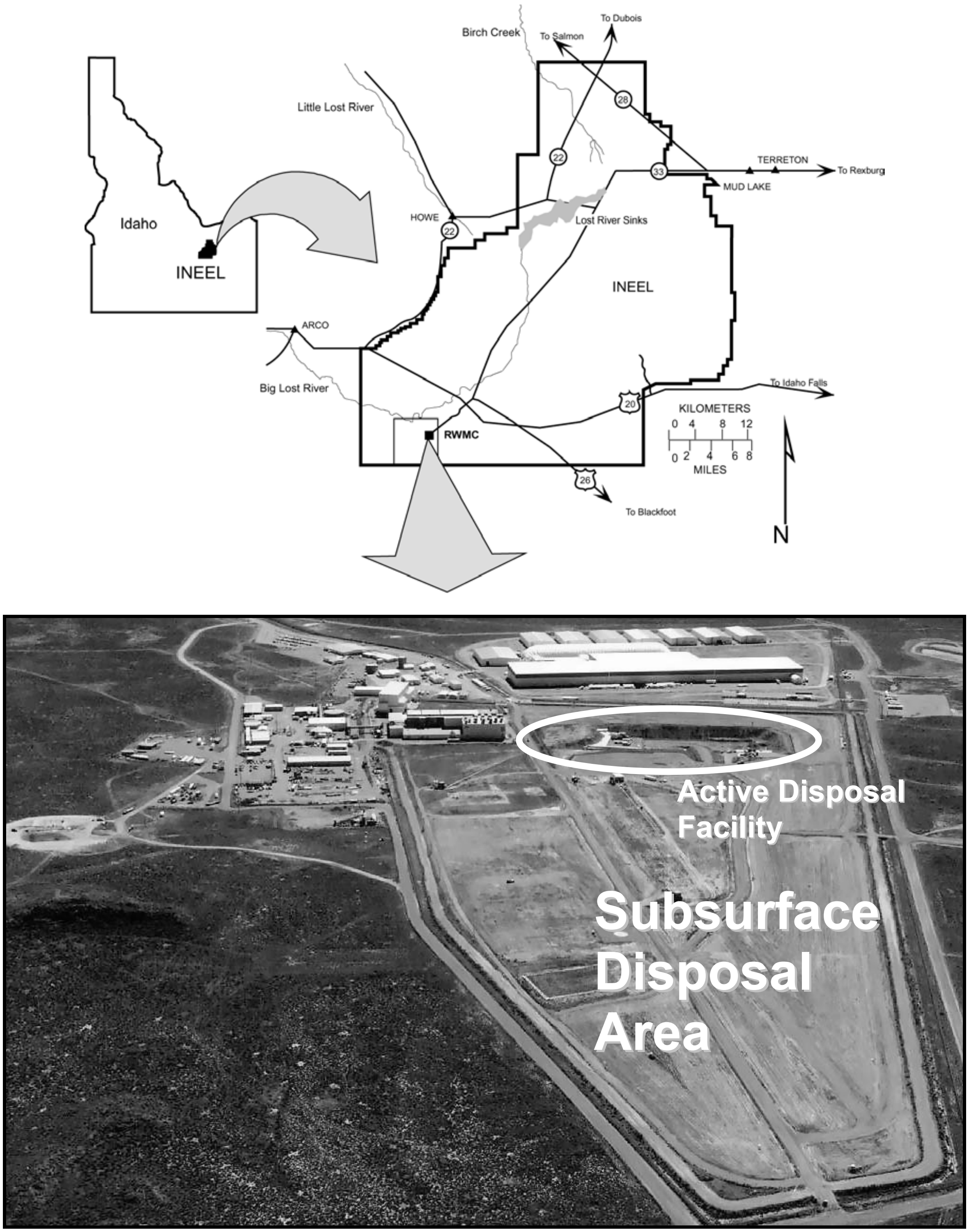

Figure 1. Radioactive Waste Management Complex and its location (Photo is rotated with north to the left).

I. VADOSE ZONE MONITORING AT THE SDA

Monitoring of the subsurface at the SDA is being performed in order to evaluate whether or not contaminant releases from the buried waste and subsequent migration in the subsurface is consistent with the assumptions and results of the PA and CA. If concentrations are found to exceed those predicted in the PA and CA simulations, the models will be reevaluated and corrective action implemented, as necessary.

Vadose zone monitoring locations are chosen near key disposal units and along the suspected transport pathway through the vadose zone. The radionuclides to be monitored and the sampling frequencies were selected based on the results of the PA and CA. In order to provide the possibility for early detection, monitoring is required in the vadose zone. The monitoring locations include the surface sediments (including monitoring within the waste disposal pits, which will begin in the near future) and interbed sediments where perched water can accumulate. Locations of the lysimeters and wells currently used to monitor perched water under the RWMC are shown in Figure 2.

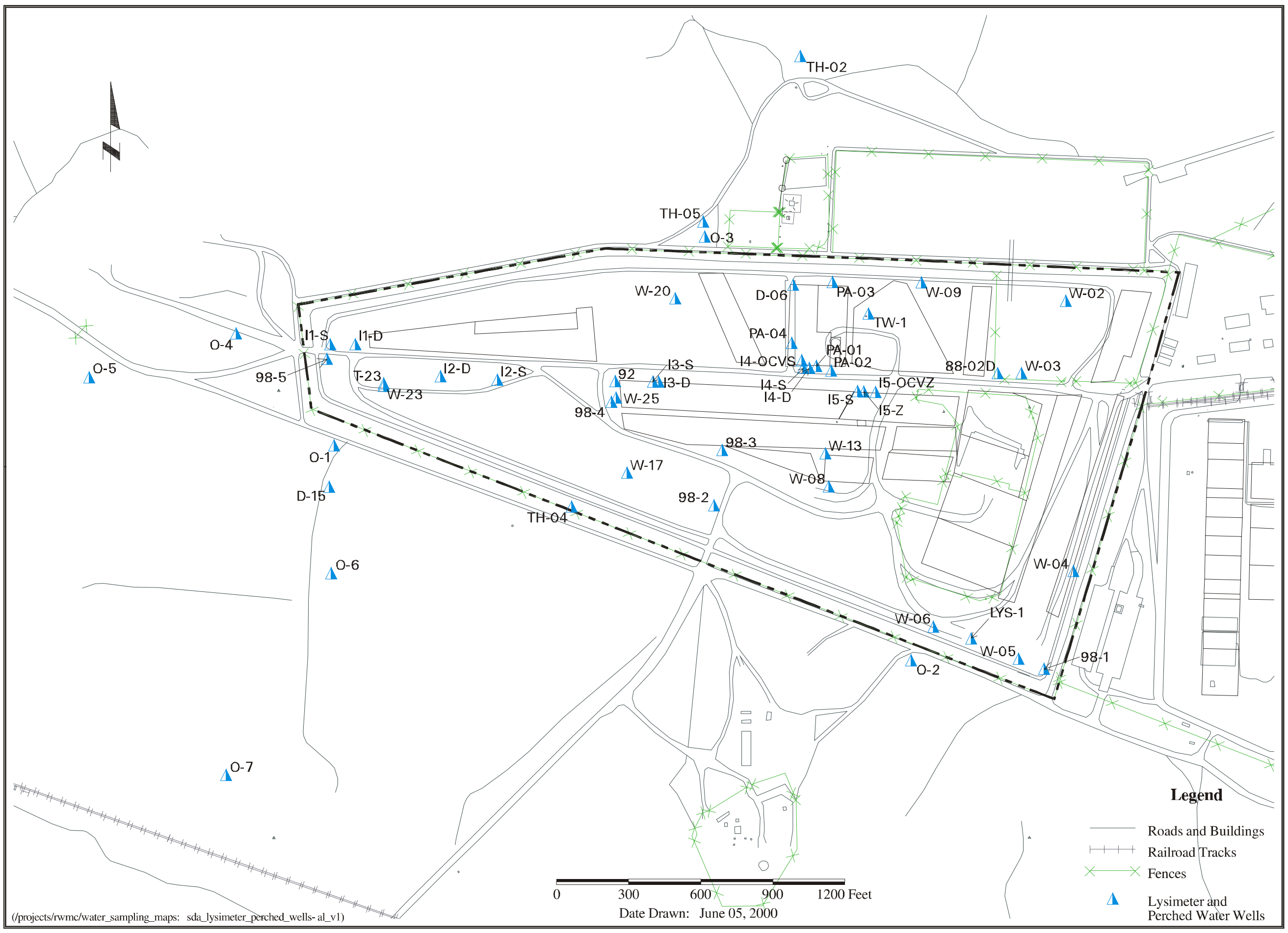

Figure 2**.** Locations of lysimeters and wells used to monitor perched water at the INEEL Radioactive Waste Management Complex.

Specific objectives of the PA/CA monitoring program are to: (1) determine current concentrations of radionuclides in subsurface waters, (2) report comparisons of measured water concentrations to vadose zone action levels, (3) detect and report significant trends in measured water concentrations of radionuclides, (4) provide a basis to evaluate actual performance versus projected performance based on PA/CA results, and (5) provide a mechanism for early detection of unexpected releases and subsurface transport that may require corrective action in order to avoid a situation where concentrations in groundwater approach the PA/CA performance objectives.

To meet the objectives discussed above, four vadose zone regions are sampled in order to provide evidence that transport in the vadose zone does not exceed the PA and CA predictions. The regions are the surface sediments, AB interbed, BC interbed, and CD interbed. Figure 3 is a schematic showing the general location of the interbeds in the vicinity of the RWMC.

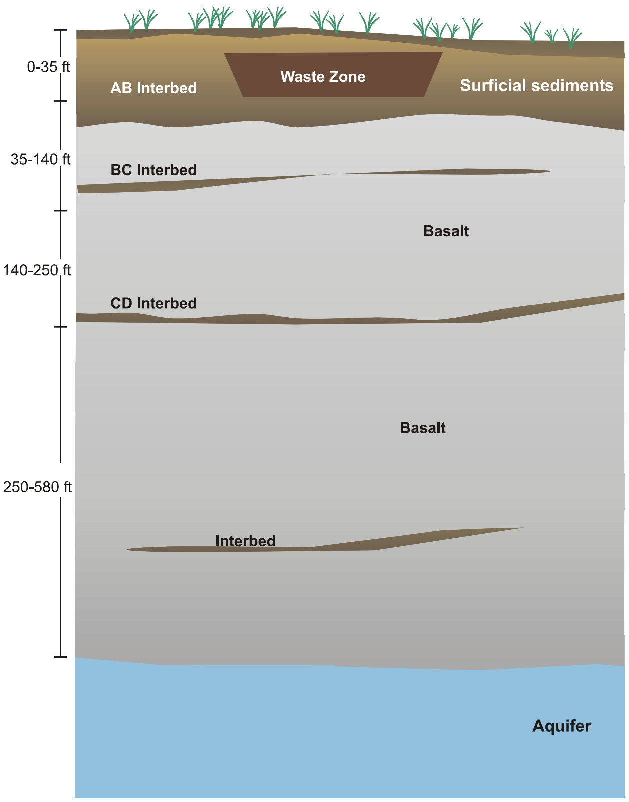

Figure 3. Conceptual stratigraphy under the RWMC.

II. DEVELOPMENT OF ACTION LEVELS

Development of action levels is required by DOE Order 435.1 in order to provide a means to integrate the monitoring program with modeling conducted to predict long-term performance of a LLW disposal facility. Action levels provide a basis with which to compare future monitoring results with PA and CA results.

Impacts from the subsurface migration of radionuclides dissolved in groundwater were estimated for both the PA and CA using computer models that described release of radionuclides from the SDA pits and vaults and migration in the vadose zone to the aquifer. Concentrations were predicted in the aquifer at a well located 100 m downgradient from the SDA active pits. Intermediate concentrations at different locations along the transport pathway were also obtained from the modeling results. Decay and sorption were included throughout the model, thus reductions in concentrations as a result of these processes are addressed in the models.

The vadose zone action levels for the LLW disposal facility at the SDA in the RWMC are established thresholds that indicate the possibility that the:

- rate at which radionuclides are moving out of the disposal area is greater than expected,
- rate at which radionuclides are being transported in the environment is greater than expected, and
- conclusions of the PA and CA may not be valid.

Fiscal Year 2001 is the first year in which the action levels were applied at the INEEL. As the modeling is updated and performance of the disposal facility is better understood, the action levels may be revised.

Vadose zone and aquifer action levels were determined based on DOE requirements and CA predicted concentrations. Concentrations projected in the CA, rather than the PA, were used to develop the action levels because the CA results are more restrictive.

C-14 is the primary contributor to the predicted aquifer all-pathways dose for the CA during the 1,000 yr compliance period. As a mobile contaminant, C-14 is predicted to reach the aquifer from the SDA (including the LLW disposal area), in the very near future. As shown in Figure 4, peak aquifer concentrations 100 m downgradient of the SDA are predicted to be approximately 100 pCi/L in the present and predicted to increase to about 1,000 pCi/L over the next 100 years (period of institutional control). The remaining curves in the figure show the predicted water concentrations in the various regions of the vadose zone that correspond to the predicted aquifer concentrations 100 m downgradient of the SDA.

The vadose zone C-14 action levels, for the year 2001, are listed in Table 1. If measured concentrations are greater than the action levels, it is an indication that assumptions used for the modeling in the PA and CA may not be conservative. This would prompt an immediate assessment of the need for corrective actions.

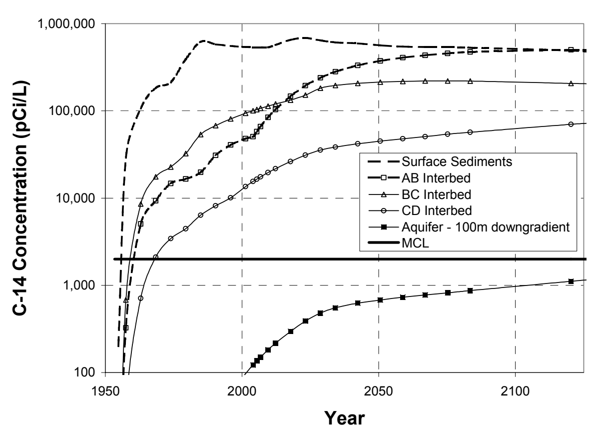

Figure 4. Predicted composite analysis C-14 concentrations in the subsurface through the 100 years period of institutional control.

Table 1. Vadose zone action levels for year 2001 based on the CA simulation results.

Nuclide	Surface Sediments (pCi/L)	AB Interbed (pCi/L)	BC Interbed (pCi/L)	CD Interbed (pCi/L)
C-14	5.4E+05	4.8E+04	9.4E+04	1.4E+04

Discontinuities in the interbeds result in predicted BC interbed concentrations that are sometimes greater that the predicted AB interbed concentrations. Regular monitoring and additional characterization of the interbeds are planned in order to verify the non-intuitive model predictions that the current peak C-14 concentration in the BC interbed is higher than the peak concentration in the AB interbed.

III. COMPARISON OF MONITORING DATA WITH MODELING RESULTS

As described in the last two sections, ongoing monitoring is used to partially characterize the current water concentrations in the vadose zone. In addition, the computer model introduced above has been developed to predict radionuclide concentrations in the vadose zone and serve as a basis to define the corresponding vadose zone action levels that if exceeded, would indicate a potential that migration may be occurring more rapidly than predicted in the PA/CA models.

The action levels are based on peak predicted concentrations in a numerical grid block. Numerical grid block sizes range from 62.5x62.5x0.5 m in the surface sediments to 250x250x2 m in the CD interbed. Therefore the predicted peak concentration in the model is actually an average over a relatively large area.

The monitoring coverage is limited, and therefore insufficient to guarantee that the water samples will represent the peak concentration. Therefore, any one sample with concentrations greater than the action level will require some form of action, because that may not necessarily be an actual peak.

As shown in Table 1, the peak predicted C-14 concentrations in the AB, BC, and CD interbeds are $4.8\text{x}10^{+4}$, $9.4\text{x}10^{+4}$, and $1.4\text{x}10^{+4}$ pCi/L. Over the last three years, vadose zone water analyzed for C-14 in the interbeds have had a maximum concentrations of 26.4 pCi/L in the AB interbed, no detected C-14 in the BC interbed, and 20 pCi/L in the CD interbed[5]. The measured C-14 concentrations in the vadose zone are about 1000 times below the action levels. The over-predictions result primarily from conservative assumptions made for CA dose assessment. Although there will never be a guarantee that the peak concentrations are measured, the fact that concentrations are well below the action levels provides confidence that the PA/CA modeling projections are conservative.

IV. FUTURE WORK

As a result of uncertainties related to the subsurface flow and transport predictions, the mechanisms controlling flow and transport are being studied within the INEEL Subsurface Science Initiative to better predict the performance of the active LLW disposal facility and the entire SDA. The objectives of these studies include improved characterization of the subsurface, increased monitoring of PA/CA critical radionuclides, development of new methods to instrument the subsurface, better understanding of source releases, facilitated transport, multiphase flow, and the effects of microbiology and geochemistry on the contaminant transport. The results of these studies will be used to better characterize water flow and radionuclide release and migration in the subsurface as needed to make the PA/CA modeling more defensible.

In conjunction with ongoing Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial investigation/feasibility study, the subsurface flow and transport simulation model is being updated. The update will incorporate recently collected information that was not available when the CA simulation model was developed. The action levels will be updated to be consistent with the results of the new simulations. If the new simulation results are significantly different from the current CA results, then the conclusions of the PA and CA will be reevaluated. Updates will be incorporated into the PA/CA annual report as needed.

IV.A. Radionuclide Release and Migration

Several research activities are underway to better quantify the release and migration of key radionuclides. Experiments are being conducted in a mesoscale column (roughly 3 m tall) as well as at the bench scale in the laboratory. Modeling is also being conducted to complement the experimental work. Because of their significance in the PA and CA results and because of uncertainties regarding their behavior in the subsurface at the RWMC, factors influencing migration of C-14 and uranium are a key concerns in this research.

The mesoscale column is filled with soils representative of the fill used at the SDA. Gas phase and liquid phase migration will be monitored. One of the major needs is to provide a basis to differentiate between the fraction of C-14 that migrates upward as a gas and the fraction that migrates downward in the liquid phase. This may explain why the predicted C-14 concentrations in the vadose zone are currently much greater than the measured concentrations. That is, much less C-14 is migrating downward than is predicted by the PA/CA models, because a substantial fraction of the C-14 is migrating upward into the atmosphere in the vapor phase.

Tritum will also be added to the column when the soil water and soil gas reaches an equilibrium state similar to conditions at the SDA. Tritium is being included in the experiment because of its high mobility in both the gas and liquid phase. Uranium is planned to be added to the column at a later date.

V. CORROSION TEST

Coupons made of stainless steel, beryllium and other metals have been placed in a soil berm near the RWMC. Over time, the coupons are being removed and examined to quantify the corrosion rate of the metals at the SDA. To date, two sets of coupons have been retrieved.

Early results of the corrosion study suggest stainless steel is corroding at expected rates and beryllium appears to be corroding somewhat faster than assumed. Given that C-14 release is assumed to be primarily controlled by corrosion, these new data may affect the assumptions made for the PA and CA leading to an eventual revision of those assessments. The current results of the corrosion test are described in detail in the latest report[6].

VI. CONCLUSIONS

Per DOE Order 435.1, monitoring and modeling have been integrated to support continued operations at the LLW disposal facility at the RWMC. Subsurface monitoring is being conducted for key radionuclides from the PA and CA and monitoring locations have been selected based on the modeling results from the two assessments. Time-dependent action levels have been specified for the different subsurface monitoring locations based on predicted concentrations from the PA and CA modeling. These action levels provide a point of reference for the monitoring results. In FY 2001, the concentrations from the monitoring results were well below the action levels, which supports the conclusion that the PA and CA modeling and the conclusions based on that modeling are conservative. Research work is also being integrated with the modeling and monitoring activities through the INEEL Subsurface Science Initiative.

VII. ACKNOWLEDGEMENTS

Work supported by the U.S. Department of Energy, Assistant Secretary for Environmental Management, under DOE Idaho Operations Office Contract DE-AC07-99ID13727.

VIII. REFERENCES

1. US Department of Energy, "Radioactive Waste Management," DOE Order 435.1 (1999).

2. J.M. McCarthy, R.R. Seitz, and P.D. Ritter, "Performance Assessment and Composite Analysis Monitoring Program," INEEL/EXT-01-00449, Bechtel BWXT Idaho, LLC, Idaho Falls, ID (2001).

3. M.J. Case, A. S. Rood, J. M. McCarthy, S. O. Magnuson, B. H. Becker, and T. K. Honeycutt, "Technical Revision of the Radioactive Waste Management Complex Low-Level Waste Radiological Performance Assessment for Calendar Year 2000," INEEL/EXT-2000-01089, Bechtel BWXT Idaho, LLC, Idaho Falls, ID (2000).

4. J.M. McCarthy, B. H. Becker, S. O. Magnuson, K. N. Keck, and T. K. Honeycutt, "Radioactive Waste Management Complex Low-Level Waste Radiological Composite Analysis," INEEL/EXT-97-01113, Bechtel BWXT Idaho, LLC, Idaho Falls, ID (2000).

5. R.R. Seitz and J.M. McCarthy, "Annual Performance Assessment and Composite Analysis Review for the RWMC Low-Level Waste Disposal Facility – FY 2001," INEEL/EXT-02-00368, Bechtel BWXT Idaho, LLC, Idaho Falls, ID (2002).

6. M.K. Adler-Flitton, et al., "Long-Term Corrosion/ Degradation Test Third Year Results," INEEL/EXT-01-00036, Bechtel BWXT Idaho, LLC, Idaho Falls, ID (2001).